98-640

Radar Recorder System

User's Manual

Developed For

Defence Research Establishment Ottawa

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ABSTRACT

On January 20, 1998, DSPCon, Inc was contracted by the Defence Research Establishment Ottawa (DREO) to design, build, and test a pulse Doppler air-to-air Digital Radar Receiver and Data Acquisition System. This system will become part of a new radar surveillance capability to be demonstrated for the Canadian Forces. DREO will use this system to gather data and to develop digital signal processing (DSP) algorithms for the new radar surveillance capabilities. DSPCon's goal was to make maximum use of commercial-off-the-shelf (COTS) hardware and software and to provide a system that fully complies with the statement of work (SOW). Although the SOW was extremely clear, some technical clarification was necessary mid way through the award period. This clarification, which was arrived at through technical discussions between DSPCon and DREO engineers, resulted in some modification of the COTS approach originally discussed.

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1.0 INTRODUCTION

The DSPCon Radar Signal Recording System is a powerful digital recording and analysis tool designed to support DREO's air-to-air Digital Radar Receiver and Data Acquisition System. The system digitally records pulse Doppler radar data at 8 megabytes per second.

A host computer (IBM-compatible personal computer) running the Data Acquisition System's advanced graphical user interface gives the operator easy control of the system operation. In addition, it can display snapshots of the radar signal in near real time.

The system records data to a digital tape drive. The system can record up to 42 gigabytes of data on a single tape, with a maximum recording rate of 12 megabytes per second.

1.1 HOW THE RADAR RECORDER SYSTEM WORKS

This system takes a signal from the radar's IF output and sends it to the Pentek Model 6441 12-bit analog-to-digital (A/D) converter. The system samples the analog input signal at 32 MHz. (The maximum possible sample rate is 41 MHz.) The digital signal is passed through a ribbon cable to the Pentek Model 4272 multiband digital receiver MIX module. Its wideband receiver performs frequency down-conversion (i.e., translation to baseband), low-pass filtering and decimation of the sampled output. The decimation factor is 16, resulting in an output data rate of 2 MHz and a corresponding 0.5 microsecond range gate. The receiver outputs the signals through the Mix bus to the Pentek Model 4284 DSP baseboard.

After decimation, a Pentek Model 4284 digital signal processor (DSP) reads each sample of the signal and performs all necessary data processing. The digital signal is then sent through the Comm Port cable to the Pentek Model 4260 SCSI Controller, which stores it on the tape drive. In addition, the DSP can send on demand a number of samples, snapshots of the signal, to the host computer for graphical display.

2.0 DIGITAL SIGNAL PROCESSING UNIT (DSP UNIT)

A Digital Signal Processing Unit consists of one Pentek 4284 DSP processor board, one Pentek 6441 two-channel Analog to Digital converter card, one Pentek 4272 digital receiver card, one Pentek 4260 differential SCSI interface card, and one MTG-110 (Sony GY-2120WD) tape drive. A block diagram of a DSP unit is shown below in Figure 1. Only the Analog to Digital converter and the DSP boards are plugged into the VME bus.

The DSP unit is responsible for:

1. Digitizing the analog data;
2. Performing any necessary data processing; and
3. Recording the data to tape.

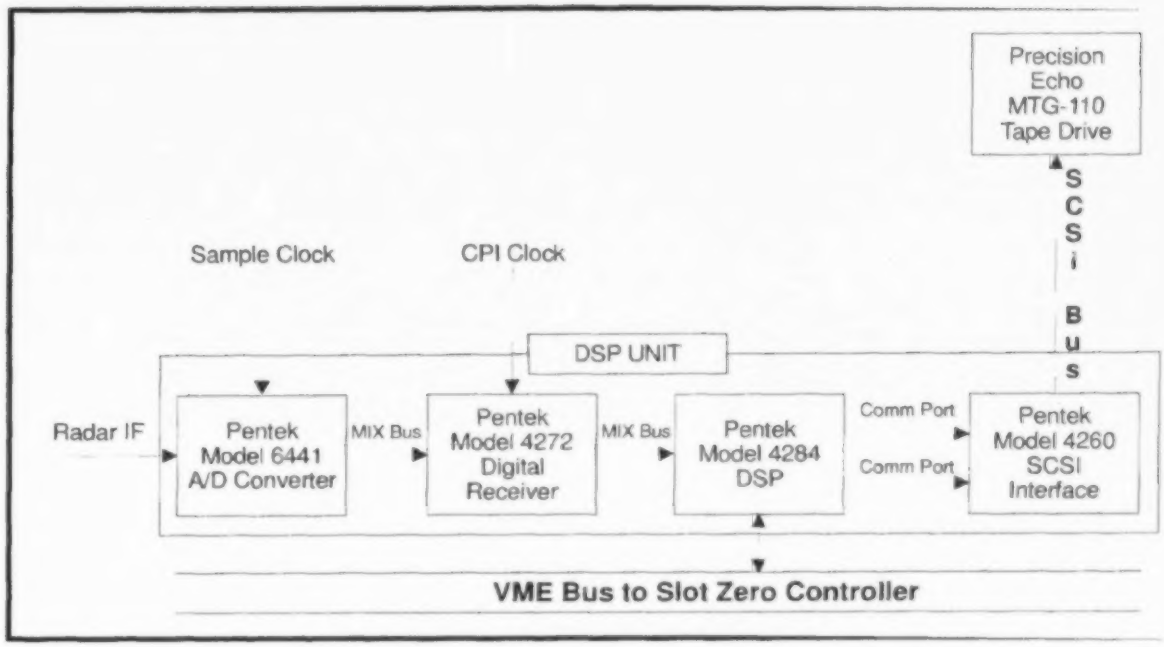

Figure 1: Digital Signal Processing Unit

A Motorola MVME162 Embedded VME Controller is provided as the Slot Zero Controller and Ethernet communication interface. This card acts as the VME bus master and network gateway between the host computer and the DSP unit. It is connected via 10 Mbps Ethernet to the host computer, and links the host computer to the DSP unit via the VME backplane. The Slot Zero Controller is also referred to in this document as the VME bus master card.

2.1 HOST COMPUTER

The host Computer is an IBM-compatible personal computer running Microsoft Windows NT. It runs the graphical user interface software.

The operator controls all system functions through the host computer, which communicates with the DSP unit via an Ethernet network using TCP/IP and Pentek's Swiftnet protocol.

2.2 HARDWARE CONFIGURATION

All components, except the host computer and the tape drive, fit inside one 19-inch rack mount VME chassis (see Figure 2). The chassis contains one Motorola MV-162 Embedded VME Controller, one Pentek model 4284 DSP, one Pentek model 4260 SCSI Interface, one Pentek model 4272 Digital receiver, and one Pentek model 6441 A/D Converter.

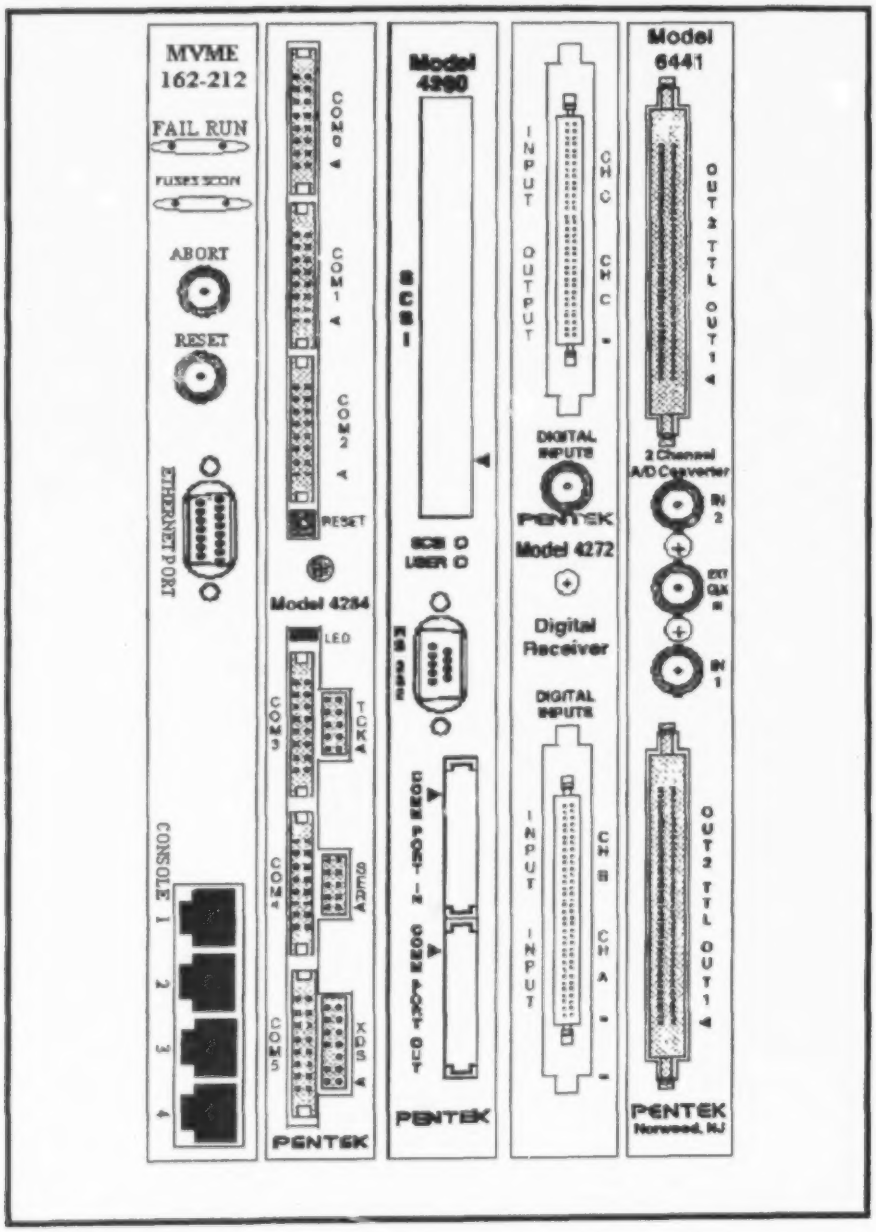

Figure 2: Hardware Configuration

3.0 JUMPER SETTINGS

In order for the system to operate properly, the DSP card must be configured as described in sections 3.1 through 3.6.

3.1 PENTEK MODEL 4260 JUMPER SETTINGS

PENTEK Model 4260 Jumper Block JB1 AND JB2	
Termpwr provided by 4260, Jumper Block JB1	Terminated Jumper Block JB2
Jumper ON Pin #1 and 2	Jumper ON Pin #2 and 3

3.2 PENTEK MODEL 4284 A16 BASE ADDRESS JUMPER SETTINGS

PENTEK Model 4284 – A16 Base Address – Jumper Block JB6					
Jumper Setting for Available Base Address					
Board Name	Hex Address	Pin 7 - 8	Pin 5 - 6	Pin 4 - 3	Pin 1 - 2
t84b	* 0x0700	ON	OFF	OFF	OFF
* Default Setting					

3.3 PENTEK MODEL 4284 A32 BASE ADDRESS JUMPER SETTINGS.

PENTEK Model 4284 – A32 Base Address – Jumper Block SW1					
Jumper Setting for Available Base Address					
Board Name	Hex Address	Pin 7 – 15	Pin 5 - 6	Pin 3 – 4,	Pin 1 - 2
t84b	* 0x0700 0000	ON	OFF	OFF	OFF
* Default Setting					

3.4 PENTEK MODEL 4284 C40 TCLK JUMPERS SETTINGS

PENTEK Model 4284 – TCK I/O Jumper Setting - Jumper Block JB5			
Pins 7 -8	Pins 5 -6	Pins 3 – 4	Pins 1 –2
OFF	OFF	* ON	* ON
OFF	OFF	* ON	* ON
* Default Setting			

3.5 PENTEK MODEL 6441 - SAMPLE CLOCK DIVIDER

PENTEK Model 6441 – Sample Clock Divider – Dipswitch SW1 Switch number and Setting (0 = Closed, 1 = Open)							
1	2	3	4	5	6	7	8
0	0	0	0	0	0	0	0

3.6 PENTEK MODEL 6441- REFERENCE CLOCK

PENTEK Model 6441- Reference Clock - Dipswitch SW2 Switch number and Setting (0 = Closed, 1 = Open)							
1	2	3	4	5	6	7	8
1	1	1	0	0	0	1	1

4.0 SIGNAL CONNECTIONS

4.1 PENTEK 4284 I/O TCK CONNECTOR

The connections on the Pentek 4284 I/O TCK Connector are as follows (see Figure 3):

- Pin #1 = CLK0 = Time-Stamp;
- Pin #2 = CLK1 = Event Marker Trigger; and
- Pins #9 and #10 = Signal Reference Ground.

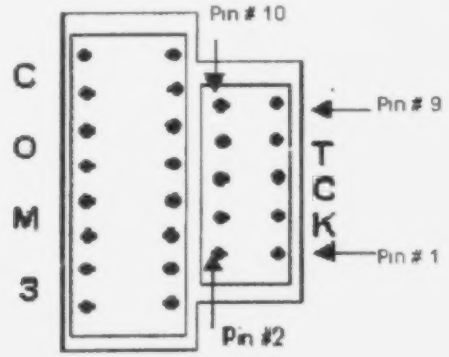

Figure 3: TCK-Time-Stamp Clock and Event Marker Trigger

4.2 CONNECTIONS FROM THE RADAR SYSTEM

The output signals from the radar system and controller must be connected to the inputs of the DSP unit as described below:

SIGNAL CONNECTIONS				
SIGNAL NAME	**INPUT/ OUTPUT**		**BOARD NAME**	**COM PORT, BNC or PIN #**
SAMPLE CLOCK	INPUT	CONNECTED TO	PENTEK 6441	EXT CLK IN
TIME-STAMP	INPUT	CONNECTED TO	PENTEK 4284	TCK PIN #1
EVENT TRIGGER	INPUT	CONNECTED TO	PENTEK 4284	TCK PIN #2
CPI CLOCK	INPUT	CONNECTED TO	PENTEK 4272	BNC Connector
RADAR IF	INPUT	CONNECTED TO	PENTEK 6441	A/D Converter IN 2

5.0 COMM PORT CONNECTION

5.1 COMM PORT CONNECTION BETWEEN 4284 AND 4260

Comm Port Connection From Pentek Model 4284 to Pentek Model 4260		
Pentek 4284		Pentek 4260
COM 2	CONNECTED TO	COMM PORT IN
COM 5	CONNECTED TO	COMM PORT OUT

5.2 DIGITAL DATA CONNECTION BETWEEN 6441 AND 4272

Digital Connection From Pentek Model 4272 to Pentek Model 6441		
Pentek 6441		Pentek 4272
OUT2	CONNECTED TO	IN PUT CH C

5.3 PENTEK 4260 SCSI INTERFACE AND TAPE DRIVE CONNECTION

SCSI INTERFACE AND TAPE DRIVE CONNECTION		
Pentek 4260		Tape Drive
SCSI	CONNECTED TO	SCSI

NOTE: there are two SCSI Connectors in the back of the Precision Echo MTG-110 tape drive. The cable from the Pentek 4260 can be connected to either one. A differential SCSI terminator must be connected to the other one.

6.0 TAPE DRIVE USAGE

The tape drive should **never** be turned off when a tape is still in the unit. If this occurs, some **data on the tape will be destroyed**. If the power fails or the drive is accidentally turned off while a tape is loaded, the display on the tape drive will say "RECOVER?". If this happens, open the front cover of the tape drive and press a thin object such as a paper clip or a pen into the hole marked "RECOVER". Tape recovery can take a long time.

7.0 SOFTWARE INSTALLATION

To install the RECORDER package on the PC host computer;

- Insert "Disk 1 of 2" into the "A:" floppy disk drive;
- From windows menu bar choose Start-> Run and type "a:\setup"; and
- Follow the installation instructions on the screen and accept all setup defaults for a typical installation.

After a successful installation, the directory and subdirectory files shown in Figure 4 will be on the C: drive.

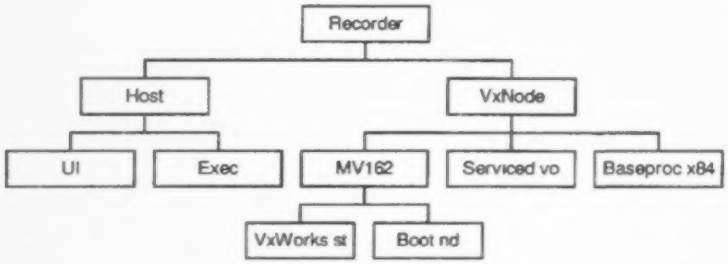

Figure 4: File Tree /Directory

8.0 CONFIGURING FOR SWIFTNET

Using the HYPERTERM terminal emulator and a local serial port, configure the MV-162 to boot from the local machine. The serial port should be configured for 9600 baud, 8 bits, 1 stop bit, and no parity. When correctly configured, a simple boot monitor interface should be available through the terminal emulator window.

To configure the MV-162 card, issue the 'c' command to the boot monitor; the boot monitor will respond with a list of questions, the answers to which are contained below:

Boot device	Use default value
Processor number	Use default value
Host name	Local machine network name
Filename	mv162/vxworks.st
Inet on ethernet	This cpu network IP address
Host inet	Local machine network IP address (Typically the IP address of the Host)
Gateway inet	Empty
User	vxnode
Ftp password	vxnode
Flags	0x08
Target name	node5
Startup script	Mv162/boot.nd
Other	Empty

If the host system's TCP/IP is configured for Domain Name Services (DNS), you will need to have the IP address registered with your network administrator. If the system is not connected to a network with a DNS server, you will have to configure TCP/IP to not use DNS and you will have to fill in the systems hosts file. Verify that the network name and IP address assigned to this CPU are known on the local machine. This can be guaranteed by adding a line to the appropriate hosts file:

C:\WINNT\SYSTEM32\DRIVERS\ETC\HOSTS	WinNT

The `hosts` file is in the same format as a standard UNIX hosts file. Typically there is a sample file called `hosts.samp` in the same directory as the hosts files. The format is as follows:

```
IP_address_of_the_host hostmachine
I/P_address_of_the_recorder
```

9.0 RECORDER PACKAGE CONFIGURATION

The recorder package includes a startup file and an initialization file that must be configured for correct operation.

9.1 CONFIGURING THE INITIALIZATION FILE

The initialization file, named `RecorderHome/host/recorder.ini`, contains all operational parameters used by the Recorder application. These parameters are:

`Node server`	Node server machine name.
`Processor name`	Fully qualified DSP processor name.
`Processor port`	Network port identifier.
`Sample rate`	# sample rate (Hz)
`Tuning frequency`	# tuning frequency (Hz)
`Number of pulse`	# number of pulses per Coherent Processing Interval
`Number of gates`	# number of range gates per pulse
`Barker compression`	# Barker compression flag

The default values for these parameters are listed below. These defaults should correctly configure the system for operation at a Pulse Repetition Frequency of 20 kHz, assuming the hardware is cabled as discussed above.

`Node server`	`"Node5"`
`Processor name`	`"/node5/t84b/0"`
`Processor port`	`8000`
`Sample rate`	`32000000.0000`
`Tuning frequency`	`8000000.0000`
`Number of pulse`	`256`
`Number of gates`	`100`
`Barker compression`	`0`

10.0 APPLICATION STARTUP

The RECORDER application requires that several helper applications be running prior to executing the main application. Use the command script "Recorder Startup", found in the Recorder program group on the start menu, to start the helper applications. These helper applications need only be started prior to the first use of the Recorder application; subsequent uses of the Recorder application will operate correctly so long as the helper applications remain running.

At startup, the Recorder application will wait while the target system is initialized. During this startup phase, denoted by the phrase "*Inoperational*" on the recorder panel, the application will appear unresponsive to user input. Once this startup phase is complete, the recorder panel will indicate the current state of the recorder.

11.0 OPERATING THE RADAR RECORDER

Under Microsoft Windows NT, the Radar's Recorder System can be started by double clicking its icon. During operation, the Recorder application presents the primary tape recorder interface display. The primary display will be similar to that shown in Figure 5.

The lower portion of the display contains operational status indicators and command buttons. The status indicators indicate operational mode, tape position, etc. The command buttons are used to control the system operation.

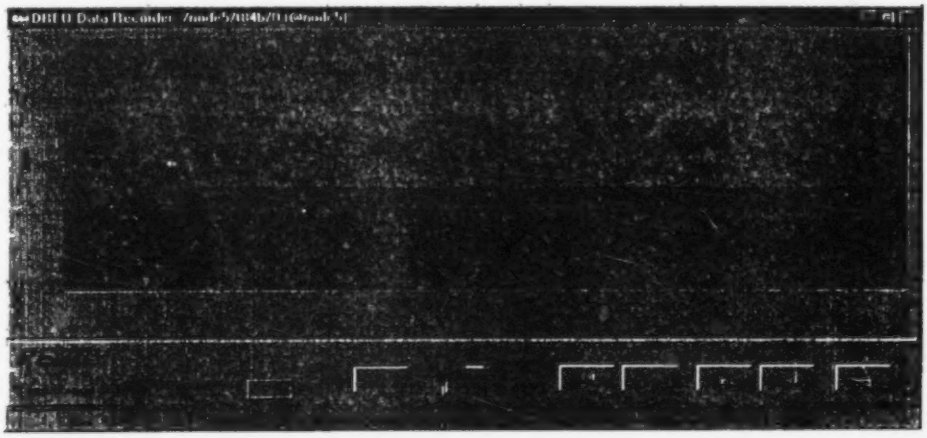

Figure 5: Main window after startup, showing a range Doppler map for a simulated target. The x-axis shows target range in units of range gates (about 75 m per gate); the y-axis shows target Doppler frequency, with pulse 1 corresponding to a Doppler frequency of 0 and pulse 128 corresponding to a Doppler frequency equal to the Pulse repetition Frequency.

The command buttons operate as follows:

- **CONFIG** - Click this button to modify the number of pulses, number of gates, tuning frequency, or dynamic range of the display. This button also is used to enable or disable the Barker compression algorithm and to chose between Doppler processing or time display. The Configuration window is described in Section 11.1. This step is not necessary if the run configuration was set previously.
- **SNAPSHOT** - Click this button to display of a snapshot of the radar signal.
- **BOM** - Click this button to rewind the tape to the beginning of the tape media. This step is not necessary if a new tape has been inserted into the tape drive.

- **EOM** - Click this button to advance to the end of the recorded portion of the tape. This is unnecessary if data were just recorded and the configuration has not changed, but is necessary if, for example, a tape with previously recorded data has just been inserted into the tape drive. This function cannot be performed while recording is active.
- **RECORD** - Click this button to start recording.
- **STOP** - Click this button to terminate recording mode. The system will change from record mode back to idle mode.
- **UNLOAD** - Click this button to unload the tape.

11.1 CONFIGURATION WINDOW

Clicking on the **CONFIG** button in the main window brings up the Configuration Window shown in Figure 6. This window allows the operator to change certain operating parameters of the data recorder. Click on each parameter's up/down arrows to change its value, or click on the value and directly type in the new value. Parameters can only be changed when the system is in idle mode.

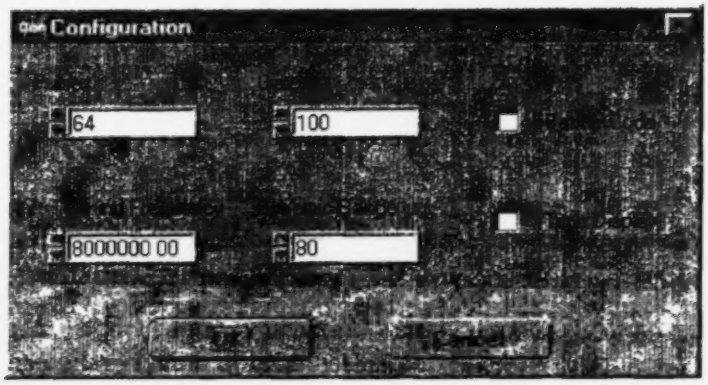

Figure 6: Configuration Window

The fields of the Configuration Window have the following functions:

- **Pulses** - This field specifies the number of pulses per Coherent Processing Interval (CPI). Valid values are from 64 to 512, in integral powers of 2.
- **Gates** - This field specifies the number of range gates per pulse. Valid values are from 100 to 533. The Pulse Repetition Frequency (PRF) is determined by the number of range gates, and is given by

  PRF = (# Range Gates) / PulseWidth,

  where PulseWidth = 0.5 microseconds is the width of the radar pulse. Therefore, 100 range gates corresponds to a PRF of 20 kHz; 533 range gates corresponds to a PRF of 3.75 kHz.
- **Tuning Frequency** - This field specifies the tuning frequency. Valid values are from 1 MHz to 16 MHz. The standard tuning frequency is 8 MHz.
- **Dynamic Range** - This field specifies the dynamic range in dB over which the data will be displayed. The display is scaled such that the brightest pixel is mapped to full white.
- **Barker Code**- When selected, this field enables the Barker Code Compression Algorithm.

- **Time Display** - When selected, the screen displays time series data instead of Doppler processed data.
- **Cancel** - Close the window without saving changes.
- **OK** - Close the window, saving any changes made.

12.0 RECORDED DATA FORMAT

A data tape is composed of a number of files, within which the recorder parameters do not change. Each file is composed of header blocks and data blocks. The header blocks is 8 words (32 bytes) long. The data blocks are variable sized. The size of each data block is from 32008 words (128032 bytes) to 64008 words (256032 bytes).

The format of the header block is as follows:

- **timeStamp** – the time stamp of the data
- **numCPI** - the number of Coherent Processing Intervals (CPI) in each data record
- **numScans** - the number of scans (pulses) per CPI
- **numSamps** - the number of samples (range gates) per pulse
- **tickCntr** - time stamp counter (500 kHz)
- **cpiCntr** - counter of the first CPI per block
- **scanIndex** - index of the scan per block
- **event** - event time stamp: 0 = no event, # = time stamp of event

The following Algorithm will determine the size of the TapeBlockSize

```
/** get cpiSize **/
cpiSize = numScans * numSamps;
DEF_BUFSIZ = 32000;
If (cpiSize <= DEF_BUFSIZ)
{
   cpiPerTapeBlock = (int) ceil ((double)DEF_BUFSIZ / cpiSize);
   scanPerTapeBlock = cpiPerTapeBlock * numscans;
}
else
{
   unsigned bufPerCpi;
   double ratio;
   ratio = (double) cpiSize / (double)DEF_BUFSIZ;
   bufPerCpi = 1 << (int) floor (log(ratio) / log(2.0) );

   cpiPerTapeBlock = bufPerCpi  ==1) ? 1 : 0;
   scanPerTapeBlock = numScans / bufPerCpi;
}

/** Calculate frame buffer **/

TapeBlockSize = scanPerTapeBlock * numSamps;
```

13.0 FAULT DIAGNOSING

13.1 PHILOSOPHY

In the event that the system does not behave as expected, the following section should serve as a guide as to what actions to take. In general, we will attempt to start diagnosing a fault from the host computer down to the tape drive. The following strategy is employed in this section:

1. Reset and restart the system. If the problem goes away, it is probably a software problem. Note the problem, save all system log files and move on. If the problem does not go away, it is probably a hardware problem. Proceed to number 2 below.
2. Follow the diagnostic procedure below. This should allow you to isolate the problem down to the board level. If so, replace the board (or boards) or contact DSPCon for a replacement.
3. If after running the diagnostic procedure you are unable to determine which board or boards are faulty, call DSPCon for help. Please have the system configuration and log files available.

13.2 PROCEDURES

The following are the steps that an operator or a technician should take to isolate a failure:

1. Check all cables and make sure that no connectors have come lose and that power is being applied to VME Card Cage. Cables include:
   - Power to VME cage. Please note there should be fans turning in the VME cage. If the power cables are plugged in and the VME cages turned on but the fans are not blowing air, then the VME cage power supply has gone bad. Call DSPCon.
   - SCSI cables running from the Pentek 4260 to the tape drive.
   - Network cable running from the host computer to the Slot Zero Controller.
2. Reset (hard and soft) all major system components to put the whole system in a known state.
   - Exit the Recorder host application.
   - Assert the reset button on the front panel of the Motorola MV-162 Slot Zero Controller. This is the card to the far left of the VME cage, in the slot labeled 0. After releasing the reset button, the LEDs on the front panel of the DSP board should start blinking. If not, it is faulty and should be replaced. Call DSPCon.
   - Within 30 seconds of releasing the Slot Zero Controller's reset, the LEDs on the front panel of the DSP (Pentek Model 4284) should stop blinking. If not, it is faulty and should be replaced. Call DSPCon.
3. Perform a variety of software probes from the host's native environment to make sure that the Ethernet connection has been established.
   - From within a shell tool or command tool (DOS window on a PC), type the following command: `> ping node5`
   - The command should result in the reply that **node5 is alive**. If it does not, the Ethernet connection is bad (check the cable).
4. Restart the application software observing the status boxes and LEDs on the hardware for obvious indications of error.
   - Follow the procedures outlined in this document for restarting the host application.
   - **Reset the DSP**. This will cause the host computer to reset and load the application code into the DSP. If an error occurs during this process, replace the DSP board. Please note

that when replacing a DSP board, make sure that all of the jumpers on the new board are set the same as the unit being replaced. These jumpers control the VME address that the board is mapped into. **Section 3.0 describes the jumper settings.**

5. Load and run the DSP application FTL on the DSP. This will allow you to probe the resources that are directly connected to the DSP.

The following directions are meant to isolate a failure down to a single board (or SCSI unit) within a DSP unit (DSP, SCSI Interface, A/D board, or A/D clocking signal). It is hoped, however, that the above directions have already narrowed the problem down to one board. Moreover, if repair time is an important issue, the best course of action is to replace the entire DSP unit and either send all components back to DSPCon, or run the following procedure when more time permits.

- Exit the host application.
- Change directory to where the FTL application has been installed.
- Start FTL on a the DSP by typing: `> pexec -b/node5/t84/0 ftl.x84`
- A graphical spinning wheel will turn for approximately 10 seconds, followed by a prompt. At this prompt, issue the command: `> probe-scsi 0`

After approximately 10 second, the following list should appear:

SCSI Address 0: Not Found
SCSI Address 1: Not Found
SCSI Address 2: Not Found
SCSI Address 3: Not Found
SCSI Address 4: Not Found
SCSI Address 5: Sony GY 2120
SCSI Address 6: Not Found
SCSI Address 7: Not Found

If the tape (at address 5) appears in this list, the Pentek Model 4260 is likely faulty and should be replaced. Call DSPCon. If tape does not appear, the tape is faulty and should be replaced. Call DSPCon.

15.0 PENTEK 4272 MODIFICATIONS

A couple of modification were made to the Pentek Model 4272 in order to allow it synchronize to the system. A BNC connector has been placed on the front panel and connected to the following pins:

- U2 pin 142
- RN11 pin 6

The signal ground of the BNC is connected to U17 Pin 10. The resistor packs RN11 and RN12 must be removed.

Two patch wires were installed on the board:

- U52 pin 2 to U51 pin 2
- U50 pin 3 to U51 pin 4

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On January 20, 1998, DSPCon, Inc was contracted by the Defence Research Establishment Ottawa (DREO) to desig build and test a Pulse Doppler air to air Digital Radar Receiver and Data Acquisition System. This system will becom part of a new radar surveillance capability to be used by Canadian Forces. DREO will use this system to gather data a to develop digital signal processing (DSP) algorithms for the new radar surveillance capabilities. DSPCon's goal was make maximum use of commercial off the shelf (COTS) hardware and software and to provide a system that will full comply with the statement of work (SOW) within the time frame of the award. Although the SOW was extremely cle some technical clarification was necessary mid way through the award period. This clarification, which was arrived a through technical discussions between DSPCon and DREO engineers, resulted in some modification of the COTS approach originally discussed.

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Pulse Doppler Radar
Digital Radar Receiver
Data acquisition System

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TITLE:(U) Radar recorder system. User's manual

CORPORATE AUTHOR: Defence Research Establishment Ottawa, Ottawa ONT (CAN);DSPCon Inc, Bridgewater NJ (US)

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